The anatomy of the wrist joint

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INTRODUCTION

Traditional descriptions of the anatomy of the wrist joint appear to be surprisingly inadequate, often conflicting, and sometimes introduce data which seem to fit into no satisfactory logical framework. For instance, only two components are generally described in the proximal articular surface of this ellipsoid joint—the distal articular surface of the radius and the triangular articular disc. The apex of the latter is said to be attached to a pit at the base of the ulnar styloid process, yet illustrations of coronal sections frequently depict a disc whose thickness apparently increases medially, even to the extent of encompassing the whole length of the ulnar styloid process. In fact, the most medial part of the proximal articular surface (contacting the triquetral) is not satisfactorily accounted for. Henle (1856), however, described an apical cleavage of the articular disc into upper and lower laminae, the former attaching to the root of the ulnar styloid process, the lower continuing as part of the curved articular surface; an aggregation of blood vessels between the two ligamentous lamellae prompted him to apply the term 'ligamentum subcruentum'. In contrast to this Testut (1904) and Poirier & Charpy (1911) described a synovial cul-de-sac (the prestyloid recess) extending from the wrist joint cavity proper into relationship with the ulnar styloid process (i.e. occupying a similar situation to the aggregation of blood vessels noted by the German author). The existence of such a synovial diverticulum has been confirmed in arthrograms (Kessler & Silberman, 1961). Then, it is known that a radiographic opacity is occasionally observed in this region adjacent to the tip of the ulnar styloid process (Olivier, 1962); moreover, the human embryo during the second to fourth months is said to exhibit a transient cartilaginous nodule at a comparable site (Leboucq, 1884; Corner, 1898).

Frequently in the past obscure anatomical regions have been elucidated by the now unfashionable discipline of comparative morphology. Varying emphasis in the components of the morphological pattern in other mammals may direct the attention to basic structures which might otherwise pass unnoticed; and understanding of the evolutionary history can provide a logical framework for the descriptive anatomical features (and their often wide variations). It is suggested here that this approach proves especially fruitful when applied to the wrist joint.
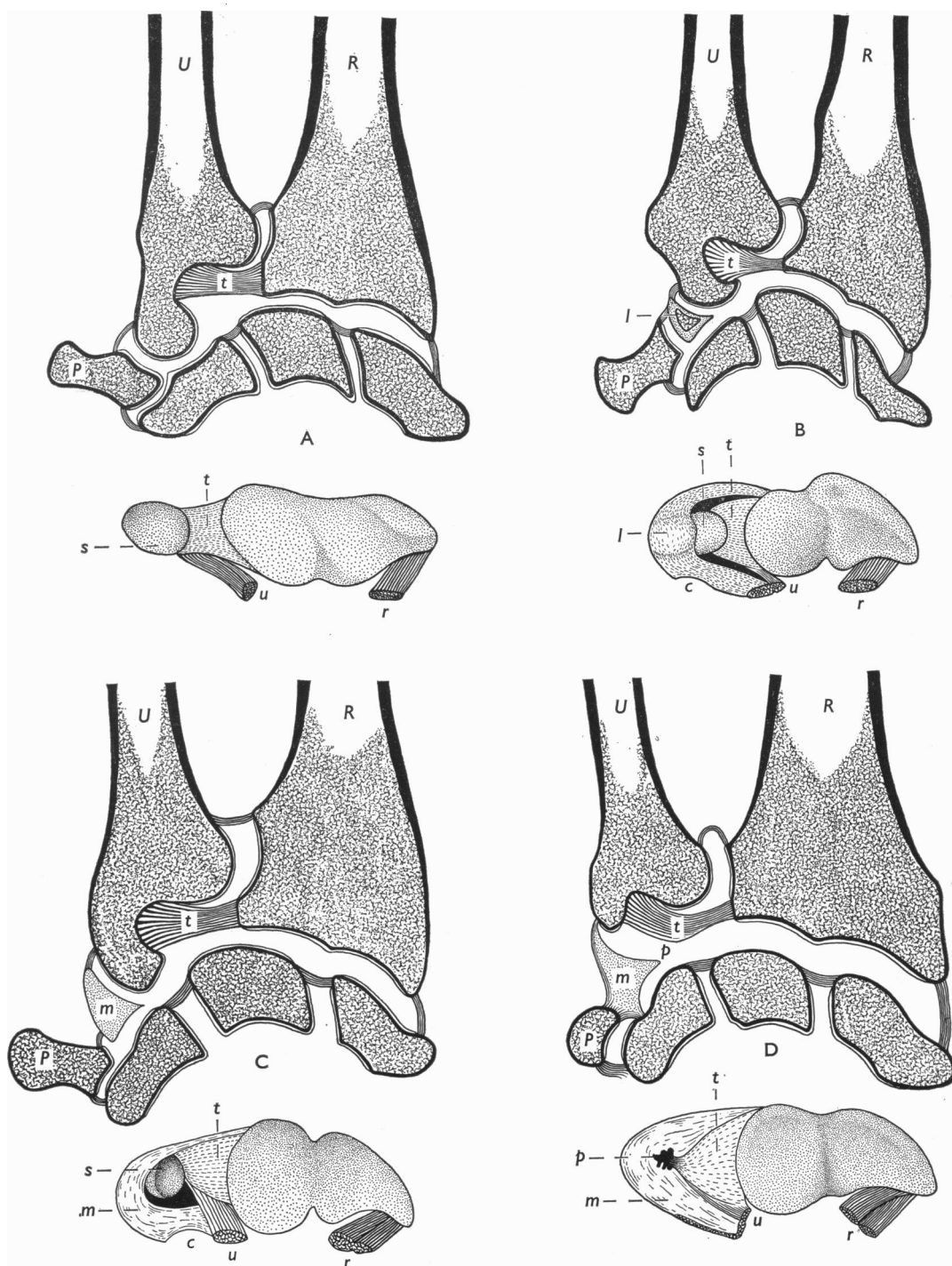
Fig. 1

Evolution of the radiocarpal joint

Primates, with the exception of the anthropoid apes, retain a primitive mammalian wrist joint pattern: the lower extremity of the ulna participates in the joint, articulating with the triquetral and pisiform bones. Monkeys, both the New and Old World varieties, show such an arrangement (Fig. 1A) and in addition exhibit in varying degree the elaboration of a synovial inferior radio-ulnar joint (incorporating a neomorphic ulnar head) at the site primitively occupied by a syndesmosis. The triangular articular disc is a derivative of the inferior capsule of this joint. All the anthropoid apes possess a fully elaborated synovial inferior radio-ulnar joint, but, furthermore, they show a striking modification (Lewis, 1965) of the wrist joint itself: an intra-articular meniscus (with a radially directed concave free margin) develops in the interval between the withdrawn ulna and the carpus. The primitive carpal articulation of the ulna has become its so-called styloid process—often an inappropriate term—which is entirely separated from the pisiform, and partially from the triquetral, by this meniscus. Around the indented anterior margin of the meniscus the pisotriquetral joint cavity is in free communication with the wrist joint cavity (except in the orang-utan). The meniscus, attached behind to the radius and anteriorly to the lunate, thus partially isolates the still articular ulnar styloid process in its own proximal synovial compartment, communicating within the concavity of the meniscus with the wrist joint proper, but quite separate from the inferior radio-ulnar joint. In gibbons (Fig. 1B) this meniscus presents an intra-meniscal ossification or lunula (the os Daubentonii). It is now well established that intra-articular menisci at a number of sites, and in various species, may exhibit such lunulae (Barnett, 1954). In the chimpanzee (Fig. 1C) the meniscus presents no lunula and may remain as a separate entity, or in some specimens may show a degree of fusion with the triangular articular disc, thus becoming an integral component of the concave proximal articular surface of the joint; in this latter circumstance the ulnar styloid process is almost completely excluded from direct participation in the wrist joint. This trend, foreshadowed in some chimpanzees, is even more accentuated in gorillas where the meniscus is well merged with the triangular disc into a confluent proximal articular surface. This effectively excludes the ulnar styloid process from the wrist joint; it is, however, still clothed with articular cartilage and still lies in a large proximal synovial compartment communicating (at least often) with the wrist joint proper via a constricted aperture. The human joint (Fig. 1D) is basically similar to that of *Gorilla* but shows a wide range

Fig. 1. The right wrist joint of A, a monkey (*Cercopithecus nictitans*); B, a gibbon (*Hylobates lar leuciscus*); C, a chimpanzee (*Pan troglodytes*); D, man (*Homo sapiens*). In each case the upper diagram represents an idealized frontal section of the articulation. Features which, due to the concavity of the carpus, do not occupy one plane are nevertheless all included here; thus, the pisiform is represented together with the three bones of the proximal carpal row—triquetral, lunate and scaphoid, from left to right in each case. The lower diagram is a view of the proximal articular surface of the same articulation, with its varying form and components.

The following features are shown: radius (*R*); ulna (*U*); pisiform (*P*); triangular disc (*t*); meniscus (*m*); intrameniscal lunula (*l*); palmar ulnocarpal ligament (*u*); palmar radiocarpal ligament (*r*); opening into prestyloid recess (*p*); site of communication between pisotriquetral and wrist joint cavities (*c*); ulnar styloid process (*s*).

of variations affecting the ulnar styloid process and the prestyloid recess (proximal compartment of the joint). The variant forms of the human joint are readily interpretable in the light of the phylogenetic history here presented. There seems little doubt that the unique wrist joint construction of the Hominoidea (the superfamily including man and the anthropoid apes) is a specialization associated with the arm-swinging method of arboreal locomotion known as brachiation. Furthermore, there is ample evidence that brachiation provided the essential apprenticeship to the bipedal posture characteristic of man. These wrist joint specializations are thus of profound significance in unravelling man's evolutionary history (Lewis, 1969).

Familiarity with Primates other than man also focuses attention on the essentials of the ligamentous apparatus of the wrist. Throughout the order the only really obtrusive ligaments are the palmar ulnocarpal and radiocarpal ligaments; their strength and disposition are obviously correlated with the primitive palmigrade posture of the limbs. These ligaments are very strong (particularly the radiocarpal one), converge from ulna and radius to the lunate, and lie intracapsularly on the flexor aspect of the joint; their considerable size may thus escape notice, and apparently usually has, unless they are viewed from within the joint. In the higher Primates the palmar ulnocarpal ligament becomes largely incorporated with the anterior margin of the emergent triangular articular disc and the palmar radiocarpal ligament extends its attachment to the capitate, thus becoming a bifascicular structure.

MATERIAL AND METHODS

Fifty wrist joints of dissecting room cadavers were specially dissected by opening the joint from the dorsal aspect by incising the articular capsule close to its carpal attachment. The radiocarpal joint cavities of three further specimens were injected with Neoprene latex prior to dissection. A further nine were injected with a radio-opaque medium (Chromopaque), radiographed, and subsequently dissected.

OBSERVATIONS

The synovial cavity

The prestyloid synovial recess is a normal feature of the human wrist joint. In the dissections of 50 joints, performed specifically to demonstrate this feature, it was found to be constantly present. It was also demonstrated by other methods: the three joints injected with Neoprene latex and subsequently dissected revealed a cast of the recess; those injected with Chromopaque clearly showed the form and extent of the recess both on radiographs (Fig. 2) and by dissection. The entrance to the recess is, logically enough, adjacent to the apex of the triangular articular disc. The opening may be masked by protruding synovial villi but freely admits a blunt probe. The size of the cavity varies considerably but it always approaches the anterior aspect of the ulnar styloid process (Figs. 3, 4). When the ulnar styloid process is actually invested by the recess (or protrudes into it) it is clothed by articular cartilage; this was so in 15 of 50 joints and in 4 of these the ulnar styloid was of such a length that, at least in ulnar deviation, it could contact the triquetral via the opening into the prestyloid recess. The ulnar styloid, in fact, varies greatly in length, mirroring its

phylogenetic (and developmental) history of progressive retreat from the carpus. In general, when the ulnar styloid process is short, projecting little if at all distal to the caput ulnae, it is not cartilage-clothed; it is the long stout ulnar styloid processes which invaginate the prestyloid recess and are cartilage-clothed.

It has already been noted that in gibbons and African anthropoid apes the piso-triquetral and wrist joint cavities are in free communication around the indented

Fig. 2. An arthrogram of the right wrist joint of a human cadaver. The wrist joint cavity is filled with radio-opaque medium (Chromopaque) which also extends into a prominent presty-loid recess related to the ulnar styloid process. The intercarpal joints are filled with Chromopaque but not the inferior radio-ulnar or pisotriquetral joints; these findings were confirmed by dissection when it was revealed that there was a deficiency in the lunate-triquetral interosseous ligament allowing access to the intercarpal joints.

anterior margin of the meniscus, where it is related to the pisiform. A similar arrangement may occur in the human joint; such a communication was found in 17 of 50 joints (Figs. 3, 4). In two of these (both included in the group noted above in which the ulnar styloid process was large and could contact the triquetral) the communication was large. Thus, an arrangement normal in other Primates may also occur in man. Most commonly, however, the pisotriquetral articular cavity is separated from that of the wrist joint. This occurs by secondary attachment of the
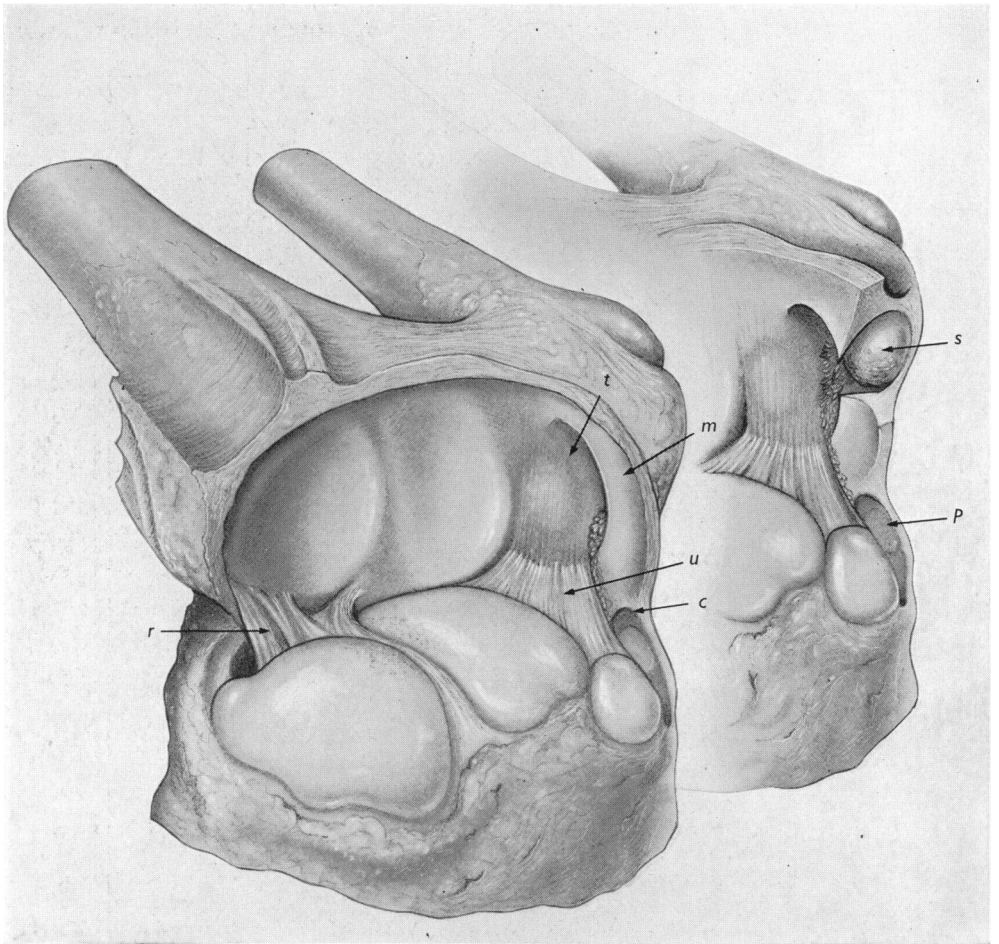

Fig. 3. The left wrist joint of a human cadaver opened dorsally and flexed. This specimen is unusual in retaining a virtually free semilunar meniscus (*m*) independent of the triangular articular disc (*t*); an arrangement very comparable to that shown in the chimpanzee illustrated in Fig. 1C has here been retained. The wrist joint cavity communicates above the free radially-directed margin of the meniscus with another synovial compartment—the prestyloid recess. In the detail shown to the right this recess has been opened by incising the meniscus to reveal a cartilage-clothed ulnar styloid process (*s*) protruding into it. The wrist joint cavity is also in communication (*c*) with the pisotriquetral cavity; the articular surface of the pisiform is shown (*P*). The palmar ulnocarpal ligament (*u*) is shown, as is the palmar radiocarpal ligament (*r*). The scaphoid exhibits a groove produced by the latter ligament.

meniscus-homologue to the triquetral (Fig. 1D); an analogous arrangement has been realized in the orang-utan.

The extensions of the radiocarpal cavity noted above are normal—the one constant, the other a variant. There may also be extensions of a degenerative pathological nature. In the series of 50 dissections 30 showed a perforation of the triangular articular disc; in 25 of these it was an antero-posterior slit but in five it was a quite large hole with a ragged margin exposing the ulnar head. Deficiencies may also occur in the interosseous ligaments uniting the lunate to the triquetral and scaphoid bones, thus bringing the radiocarpal and intercarpal joints into communication;
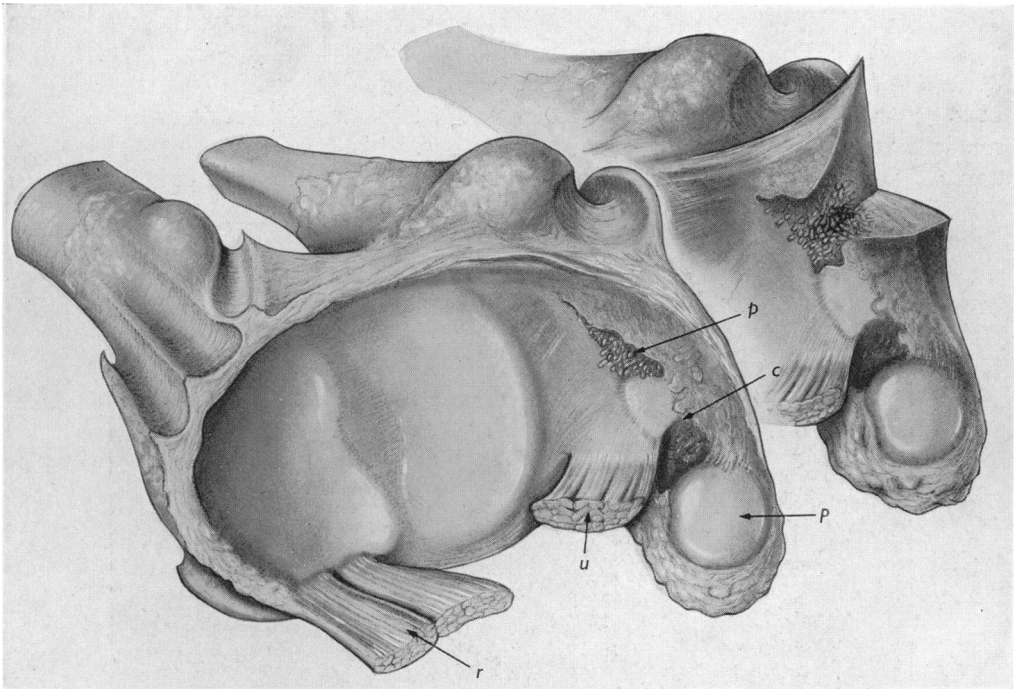

Fig. 4. The upper articular surface of the left wrist joint (together with the pisiform, (*P*)), of a human cadaver, with the two bands of the palmar radiocarpal ligament (*r*) cut from their attach-. ments to lunate and capitate and the palmar ulnocarpal ligament (*u*) cut from the lunate. This specimen illustrates the arrangements when the prestyloid recess fails to extend up to the ulnar styloid process (which is not, therefore, clothed with articular cartilage). The opening (*p*) into the prestyloid recess is masked by a protruding mass of synovial villi and the meniscus, as is usually the case, has lost its separate identity, becoming the most ulnar part of the proximal articular surface. In the detail shown above the prestyloid recess has been opened by an incision revealing a luxuriant growth of synovial villi arising from the lining membrane. In this specimen there was continuity (*c*) between the radiocarpal and pisotriquetral joint cavities. The latter joint cavity (as is often the case) is ballooned proximally to the pisiform bone (*P*) itself.

these ligaments form a greater part of the distal articular surface of the joint than is usually appreciated. In the series of 50 dissections there was perforation of the lunate-triquetral ligament in 18, and of the lunate-scaphoid ligament in 20. It must be remembered that all these specimens were from elderly dissecting room subjects and

presumably such abnormal communications with the radiocarpal joint are degenerative phenomena. These sequelae to degeneration are not, however, restricted to the aged for Kessler & Silberman (1961) have recorded defects in the triangular articular disc in males of 42 and 29 years and observed that tears may also be traumatic.

The bony lunula

Radiologists and anatomists have long been aware of the occasional ($\frac{1}{2}$–1%) presence of discrete radiographic opacities adjacent to the tip of the ulnar styloid process (Bizarro, 1921; Izquierdo, 1925; Lecoux, Lebard & Guy, 1949; Grashey & Birkner, 1965; Gui, Busanelli & Trabucchi, 1966). The present authors have observed these ossicles in a number of radiographs. Figure 5 is an example in which the anomaly was bilateral and there was no history of injury. Such opacities have been given various names—ulnare antebrachii, triquetrum secundarium, os intermedium antebrachii, os triangulare, os styloides. This diversity of terms reflects to some extent uncertainty over the nature of these ossicles. Some authors maintain

Fig. 5. A radiograph of the right wrist joint of an adult human female. A bony lunula (triquetrum secundarium or triangulare) is clearly shown between the tip of the ulnar styloid process and the pisiform. A radiograph of the left wrist of this patient exhibited a similar ossicle and there was no history of injury.

that all result from ununited fractures of the styloid process. Others hold the view that they represent true carpal morphological elements. Still others suggest that they represent detached supernumerary ossific centres for the styloid process. This last concept rests on the very doubtful assumption that the ulnar styloid process occasionally ossifies from a separate centre; Borovansky & Hnevkovsky (1929) and Flecker (1942) are cited in support of this notion. There is, however, little doubt that these authors were describing the separate ossicle itself and not a condition which could be construed as predisposing to it. In fact, there can be little doubt, in the light of the comparative findings described above, that these ossicles are of the same nature as the os Daubentonii of the gibbon, i.e. they are lunulae and represent ossifications of the normally transient cartilaginous nodule found at the same site in the human embryo.
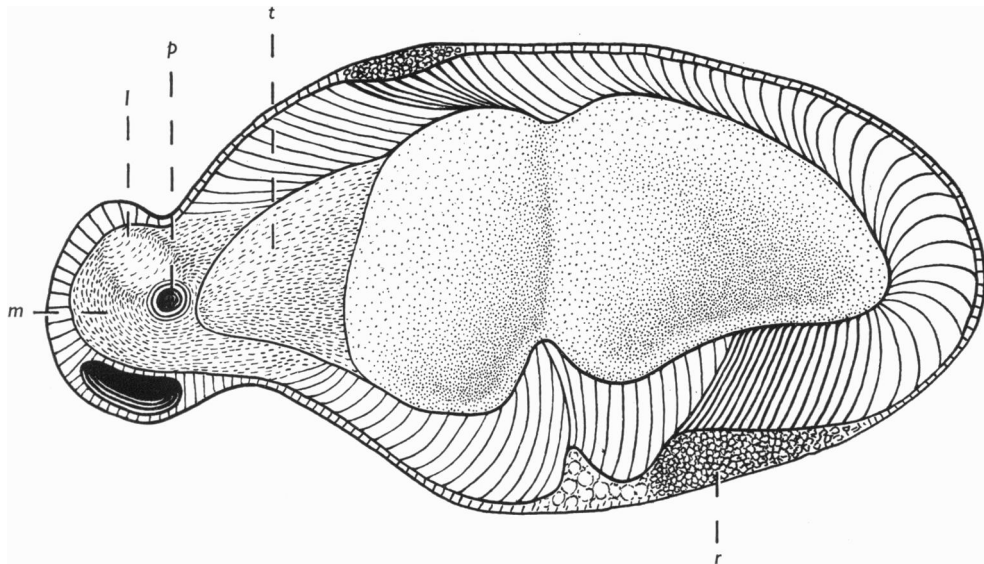

Fig. 6. A diagrammatic representation of the upper articular surface of a right wrist joint in which there was a bony lunula (*l*) (triquetrum secundarium or triangulare) embedded in the tissues of the meniscus-homologue (*m*). In this specimen also (cf. Fig. 4) the pisotriquetral joint cavity ballooned proximally to the pisiform bone. The following features are also shown: opening into prestyloid recess (*p*); palmar radiocarpal ligament (*r*); triangular articular disc (*t*).

In the 50 specimens one example of this ossicle was found, and for the first time its relationships to the soft parts could be observed. (The only previous recorded example of the actual bone is that of Pfitzner, 1895, but this was in a macerated osteological preparation.) The bone clearly lay in a comparable situation to that of the os Daubentonii—the intrameniscal lunula of gibbons—i.e. it was embedded within that part of the proximal articular surface derived from the meniscus (Fig. 6).

The ligaments

Textbook descriptions mention various membranous bands of parallel fibres, derived from the fibrous capsule of the joint, but lay particular emphasis on none; on comparative grounds this is highly improbable. In fact, as is to be expected from the evolutionary history of the joint, the really significant accessory ligaments are located anteriorly, are essentially intracapsular (and therefore are best seen by opening the joint dorsally), and converge from radius and ulna onto the centrally situated bones of the carpus.

The radiocarpal ligament is a massive structure, subdivided into two bands on its internal aspect. It is by no means a mere flat membranous sheet, as most textbooks suggest; this is an erroneous impression arising from viewing the joint only from the exterior. It arises from a large smooth impression on the anterior aspect of the styloid process of the radius (Fig. 7). Surprisingly, this facet has almost invariably excited no comment. The two bands pass to be attached to the anterior aspect of the lunate and capitate (Figs. 3, 4). In its intracapsular course it is lodged in a groove (frequently lined by cartilage) on the scaphoid bone proximal to its tubercle; the concave anterior aspect of the scaphoid is, in effect, moulded onto the ligament.
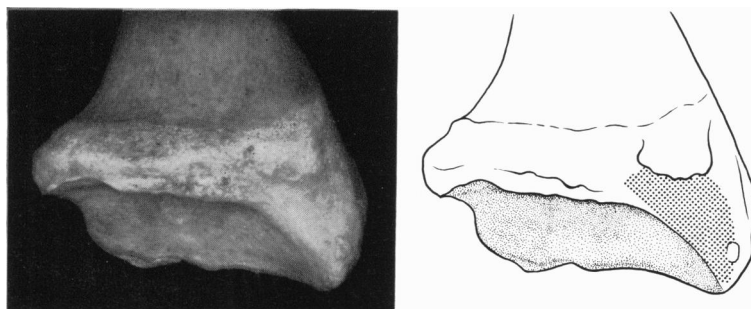

Fig. 7. The macerated radius of the specimen illustrated in Fig. 4 showing the large smooth area on the anterior aspect of the styloid process for the attachment of the anterior radiocarpal ligament; in the accompanying line diagram the area of this attachment is indicated by the dark mechanical stippling.

The palmar ulnocarpal ligament has largely lost its primitive separate identity by merging with the anterior margin of the triangular articular disc. When the joint is opened dorsally (Fig. 3) the impression is gained that the antero-lateral angle of the disc has a considerable attachment to the front of the lunate; it presents as a prominent synovial-covered protrusion into the joint in this region. Dissection of this mass reveals that it contains a variable amount of ligamentous fibres arising from the fossa between the head and styloid process of the ulna (together with the triangular articular disc) and attaching distally to the lunate.

Canonical descriptions invariably stress the presence of radial and ulnar collateral ligaments, a notion that seems justified by the appearance of coronal sections. In fact, man (along with the other members of the order Primates) possesses no separate entities justifying such a description. It is true that, where the massive palmar radiocarpal ligament grooves the scaphoid bone, the investing fibrous

capsule is attached to the scaphoid tubercle. This may give the erroneous impression of a strong collateral ligament here; in fact, there is but negligible specialization of the fibrous capsule in this situation. Similarly, there is little to justify the concept of a definite ulnar collateral ligament arising from the tip of the ulnar styloid process: it has been shown above that this process is commonly free of all ligamentous attachments, clothed with articular cartilage, and protruding into the prestyloid synovial recess. When the pisotriquetral joint is sealed off from the radiocarpal joint, the separation has been effected by attachment of the meniscus-homologue to the triquetral (Fig. 1 D); in such cases there is a strengthened attachment between proximal and distal articular surfaces which perhaps justifies description as at least the ulnotriquetral band of an ulnar collateral ligament.

The dorsal fibrous capsule is relatively thin but presents a thickened band—the dorsal radiocarpal ligament running from the radius to the triquetral.

DISCUSSION

The phylogeny of the human wrist joint

It has been demonstrated that the human joint shows a considerable range of variation, affecting particularly the ulnar part of the proximal articular surface. These variations are, however, readily interpretable in the light of the phylogenetic history summarized above. A prestyloid synovial recess is constantly present and is clearly derived from the proximal compartment of the wrist joint cavity, constricted off by a meniscus developed in association with retreat of the ulna from the carpus. Indeed, a relatively independent meniscus may occasionally occur in man mimicking the condition seen in certain pongids. More often the meniscus fails to retain its separate identity, becoming merged with the remainder of the proximal articular surface, and it frequently loses its articular character by becoming attached to the triquetral thus sealing off the pisotriquetral joint cavity from its primitive continuity with the radiocarpal joint. On occasions the human meniscus-homologue may even contain a bony lunula.

Development of human wrist joint

A detailed study of the development of the human joint is in progress and will be published elsewhere. It is significant in the present context, however, that the phylogenetic stages postulated for the human joint are recapitulated during development: the ulna initially contacts the triquetral and pisiform but subsequently recedes, the meniscus-homologue (more clearly defined than is usual in the adult) appearing in the interval, and with it the prestyloid synovial recess. For a time, at least, the pisotriquetral and radiocarpal joint cavities are often in communication as noted above in anthropoid apes. The transient appearance of a cartilaginous nodule (and its occasional ossification and persistence in the adult) at the site occupied by the gibbon lunula leave little doubt that the phylogeny of man included a stage where the wrist joint was similar to that of gibbons with a meniscus containing a bony lunula.

The elaboration of the accessory ligaments of the joint (with their typical appearance, distinctive from that of the developing fibrous capsule) can be clearly followed in foetal joints. A thick palmar radiocarpal ligament, a thinner dorsal radiocarpal

ligament and a variable palmar ulnocarpal ligament are all clearly apparent; collateral ligaments distinct from the fibrous capsule, however, are not identifiable.

Surgical anatomy of the wrist joint

Rheumatoid arthritis. It is well recognized that pain and soft tissue swelling (Lewis, 1955) on the ulnar side of the wrist joint are almost pathognomonic signs of early rheumatoid arthritis. Even more significantly, small bone erosions of the ulnar styloid process (Fig. 8) are a characteristic radiological sign (Simon, 1965); in late stages the ulnar styloid process may be almost completely absorbed. Now it is well established that the primary lesion in rheumatoid arthritis involves the synovial membrane, with great hypertrophy of the synovial villi and proliferating pannus formation. On this basis traditional anatomical descriptions offer no explanation for

Fig. 8. A radiograph of the right wrist of a patient showing an early rheumatoid erosion of the ulnar styloid process.

early involvement of the ulnar styloid process. In this study the constant relationship of the (often articular-cartilage clothed) ulnar styloid process to the prestyloid recess has been demonstrated. The highly vascular and active nature of the synovial membrane forming the walls of what is essentially a diverticulum of the radiocarpal joint has also been noted. There is little doubt that this already active synovial membrane is early involved in rheumatoid arthritis, leading to the characteristic clinical and radiological signs in the region of the ulnar styloid process; indeed, this has been confirmed by the authors in specimens removed at operation, where the character-

istic picture of increased vascularity and lymphocytic infiltration with great villous hypertrophy has been demonstrated in the wall of the prestyloid recess. With the present vogue for synovectomy in early cases of rheumatoid arthritis of the wrist (Linscheid, 1968), the existence of a proximal compartment of the joint cavity—the prestyloid recess—at the location of the earliest symptoms and signs merits careful attention.

Fractures, dislocations and fracture-dislocations. Knowledge of the predominant role played by the palmar ulnocarpal and radiocarpal ligaments in the ligamentous apparatus of the wrist has considerable relevance to the understanding of the very common injuries in this region resulting from falls on, or over, the outstretched hand. These are, in effect, hyperextension injuries, and in this position the thick palmar ligaments are clearly under great tension.

This type of injury may result in a variety of dislocations or fracture-dislocations of the carpus (Watson-Jones, 1955). One significant feature is common to all these injuries: the carpus separates into two component parts consisting of the lunate (with or without the scaphoid or its proximal part) and the remainder of the carpus. The lunate may retain its normal position whilst the remainder of the carpus is dorsally dislocated about it—perilunar dislocation of the carpus. Conversely, it may be the lunate which is dislocated forwards. In the light of the anatomical arrangements described above, the underlying mechanism becomes obvious. The lunate is retained anteriorly by the converging palmar ulnocarpal ligament and the exceptionally strong palmar radiocarpal ligament whilst the remainder of the carpus dislocates. Perilunar dislocation of the carpus is commonly associated with fracture of the scaphoid—trans-scaphoperilunar dislocation of the carpus. It is plausible to suppose that the strong palmar radiocarpal ligament, intimately related to the scaphoid proximal to its tubercle, is responsible for shearing off this part of the bone, whether or not there is an obvious associated carpal dislocation.

The occasionally occurring bony lunula adjacent to the ulnar styloid process merits clinical attention and should obviously be distinguished from fractures of the ulnar styloid process.

SUMMARY

1. New information is presented relating to the comparative morphology of the human radiocarpal joint.

2. In addition to the usually described components (radius and triangular articular disc) of the proximal articular surface, consideration must be given to an intra-articular meniscus on the ulnar side which merges to a varying degree with the other two components.

3. This meniscus is responsible for isolating the ulnar styloid process (which may preserve an articular character) in a proximal diverticulum of the wrist joint cavity— the prestyloid recess.

4. The synovium of the prestyloid recess may be early involved in rheumatoid arthritis; it is suggested that this is responsible for pain and swelling on the ulnar side of the wrist and for the characteristic radiological sign of erosions of the ulnar styloid process.

5. Primitively the meniscus contained an intrameniscal ossification (lunula)

which occasionally also occurs in man; it should be distinguished from an avulsed ulnar styloid process.

6. Man retains a primitive ligamentous apparatus at the wrist, the essentials of which are seldom adequately recognized. The probable role of these ligaments in the aetiology of fractures and dislocations is discussed.

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